PACE: How One NASA Mission Aligns With the United Nations Decade of Ocean Science for Sustainable Development (OceanShot #2)

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ABSTRACT

The PACE satellite observatory will follow a Sun synchronous, polar orbit at an altitude of 676.5 km with a local 13:00 Equatorial crossing time. Its payload consists of three instruments, a primary hyperspectral imaging radiometer being built at NASA Goddard Space Flight Center and two multispectral, multiangle polarimeters, the combination of which advances far beyond heritage capabilities. The Ocean Color Instrument (OCI) offers one-day global coverage with a ground sample distance of 1 km2 at nadir. As described in this OceanShot, this leap in technology will enable improved understanding of aquatic ecosystems and biogeochemistry, as well as provide new information on phytoplankton community composition and improved detection of algal blooms.

OCI will be complemented by two small multi-angle polarimeters with spectral ranges that span the visible to near infrared spectral region. When sunlight interacts with clouds or aerosols, it comes away from that interaction changed. By measuring changes in how reflected light oscillates within a geometric plane (i.e., its viewing angle-specific polarization), we can infer useful properties of the clouds or aerosols. This information is crucial to deciphering the way sunlight is reflected and absorbed by our planet and how aerosols affect cloud formation. The polarimeters include the Spectro-polarimeter for Planetary Exploration (SPEXone) and the Hyper Angular Research Polarimeter (HARP2), both of which will significantly improve aerosol and cloud characterizations and provide opportunities for novel ocean color atmospheric correction. (Figure 3). These instruments offer complementary capabilities: SPEXone is hyperspectral, multi-angular, and narrow swath to support advanced atmospheric aerosol characterizations, whereas HARP2 is multispectral, hyper-angular, and wide swath to advance cloud property retrievals. In total, the combined PACE instrument suite will revolutionize studies of global biogeochemistry, carbon cycles, and air–sea exchanges in the ocean–atmosphere system.

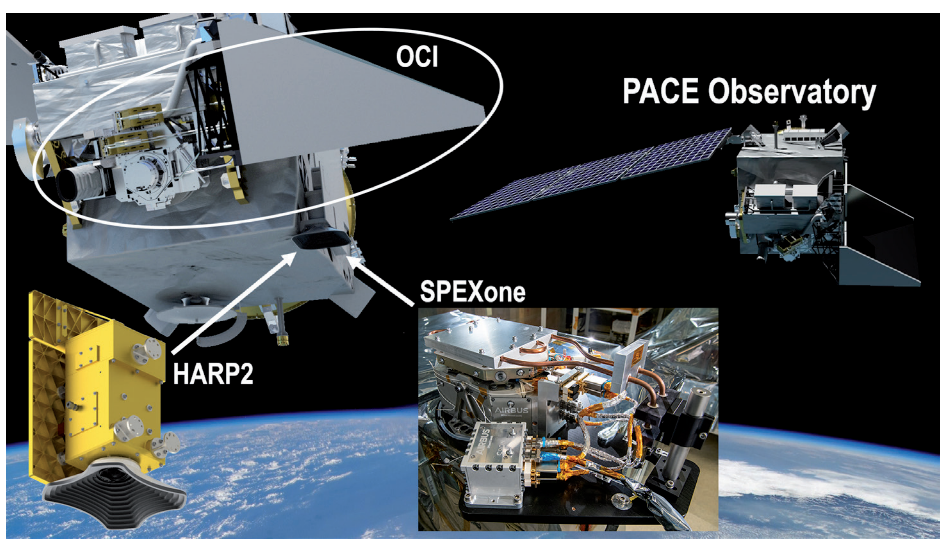

FIGURE 3. This visualization shows the PACE observatory with three instruments highlighted in the inset at upper left: Ocean Color Instrument (OCI) and two polarimeters, SPEXone and HARP2. SPEXone is contributed by a Netherlands-based consortium consisting of the Space Research Organization of the Netherlands (SRON) and Airbus Defence and Space Netherlands. HARP2 is being developed by the Earth and Space Institute at the University of Maryland Baltimore County. (Image modified from NASA Conceptual Image Laboratory).

A Safe Ocean

Tiny algae can have huge impacts on life and livelihoods ... particularly when it comes to toxic and harmful algal blooms (HABs). HABs occur when phytoplankton grow out of control while producing toxic or harmful effects on organisms. While we know of many factors that may contribute to HABs, how these factors come together to create "blooms" is not universally understood today. PACE data will aid in the development of cutting-edge tools used to understand the environmental factors that govern the appearance and demise of HABs.

Consequences of HABs are multifold. Environmental impacts include the alteration of marine habitats, which impact the organisms that depend on them. Human health issues include illness—or even death—from eating contaminated shellfish. Other HAB toxins are tiny airborne particles—aerosols—that can trigger asthma attacks. There are also socio-economic ramifications of HABs resulting from decreases in tourism, recreation opportunities, and commercial fishing production. In fact, coastal HAB events in the United States have been estimated to result in economic impacts at least $82 million each year.

FIGURE 4. PACE observations will be calibrated with novel in-water instruments. Left: The Marine Optical Network (MarONet) platform has a moored buoy design with sensors at the surface and three fixed depths. Advanced optics and hardware allow simultaneous acquisition of irradiance (i.e., flux of radiant energy per unit area) above and below the ocean surface, both in downwelling and upwelling directions. MarONet will likely be deployed off of the coast of Perth, Australia to provide a geographically diverse complement to its predecessor, the Marine Optical BuoY (MOBY), a NOAA-funded project located off Lanai, Hawaii, that has provided vicarious calibration of ocean color satellites for decades. Right: HyperNav is a Lagrangian float that can adjust its buoyancy to operate in near-surface or profiling modes. It measures hyperspectral in-water irradiance. HyperNav is a fully portable system, allowing assessment of various geographical locations and within physical oceanographic features such as ocean eddies. (Image sources: K. Voss, University of Miami and A. Barnard, Sea-Bird Scientific).

Members of the PACE science team members are actively involved with the Cyanobacteria Assessment Network (CyAN), a multi-agency project to develop an early warning indicator system for algal bloom detection in U.S. freshwater systems. CyAN uses satellite data to support federal, state, and local partners in their efforts to assess water quality and thus protect aquatic and human health. PACE data products will help projects such as CyAN improve the decision-making ability of water managers responsible for monitoring and assessing both freshwater and estuarine systems.

A Clean Ocean

PACE is engaging communities of scientists, policy makers, public health practitioners, and industry professionals around the globe. These communities will apply PACE data to tackle research questions that support a clean ocean. The mission established a network of Early Adopters, as well as a Community of Practice, with the purpose of fostering new partnerships and out-of-the-box thinking that will generate inventive solutions that aid society.

Their work is centered around an Applications Capability Matrix framework—a tool used to identify pathways the mission will contribute to addressing fundamental applied science questions above and beyond its core objectives—including:

- When oil leaks, seeps, or spills into the environment, how do we know its amount and impact?
- How does coastal water quality affect aquaculture site selection and fishery operations?
- How does climate change impact water-borne pathogens in coastal waters and estuaries?
- Where do algal blooms occur? How do environmental factors enhance and respond to algal blooms?
- How do ocean organisms affect the atmosphere and coastal air quality?
- How does water clarity information help monitor estuary health, river outflow, and manage resources?
- Become part of the PACE Community of Practice by signing up here: https://pace.oceansciences.org/app_CoP.htm

A Transparent and Accessible Ocean

NASA promotes the full and open sharing of all data with the research and applications communities, private industry, academia, and the general public. PACE science data products will be made available to the public through a NASA-designated Earth science data center, after a 60-day post-launch initial orbit checkout phase, with an expected data latency of 3 to 12 hours (i.e., average time under normal operating conditions between data acquisition by the PACE observatory and delivery to the data center). All PACE data will be served by NASA's Ocean Biology Distributed Active Archive Center (OB.DAAC), responsible for archiving satellite ocean biology data produced or collected under NASA's Earth Observing System Data and Information System (EOSDIS). The OB.DAAC also hosts SeaDAS, a publicly available, comprehensive software package for the processing, display, analysis, and quality control of ocean color data. SeaDAS not only provides an approachable tool for visualizing ocean color data, but also the processing tools to exactly reproduce (or modify) the geophysical retrievals distributed by NASA.

An Inspiring and Engaging Ocean

Thanks to PACE, ocean science is on the brink of extraordinary discoveries. By partnering with the UN Decade of Ocean Science for Sustainable Development, the mission seeks to extend its reach and more broadly share the science data we need for the ocean we want. In addition to ensuring data and software accessibility, the PACE mission offers routine community-wide workshops (e.g., the 3rd PACE Applications Workshop will be held in September 2022), access to a Community of Practice, live trainings (e.g., a graduate-level course on the mission for students and early career professionals will occur in August 2023), online resources, and active participation in community outreach events.

By making the leap from global multispectral radiometry to spectroscopy, PACE will revolutionize our scientific understanding of phytoplankton community composition and, more broadly, change the game regarding our ability to monitor aquatic eco-systems and their interactions within Earth's changing climate.